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TRANSITORY FIRE RESISTANCE OF TANKER LIFEBOATS.(U)
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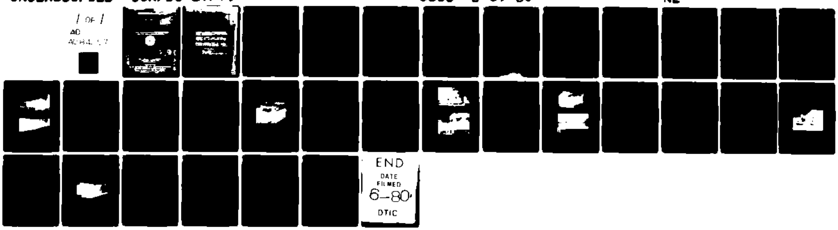

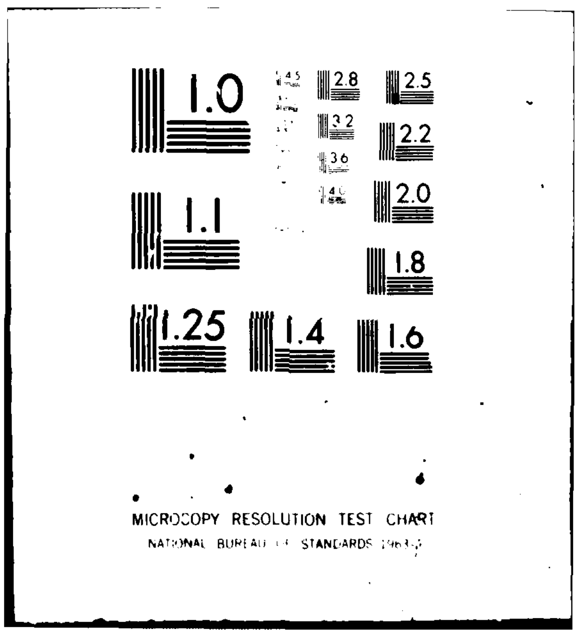
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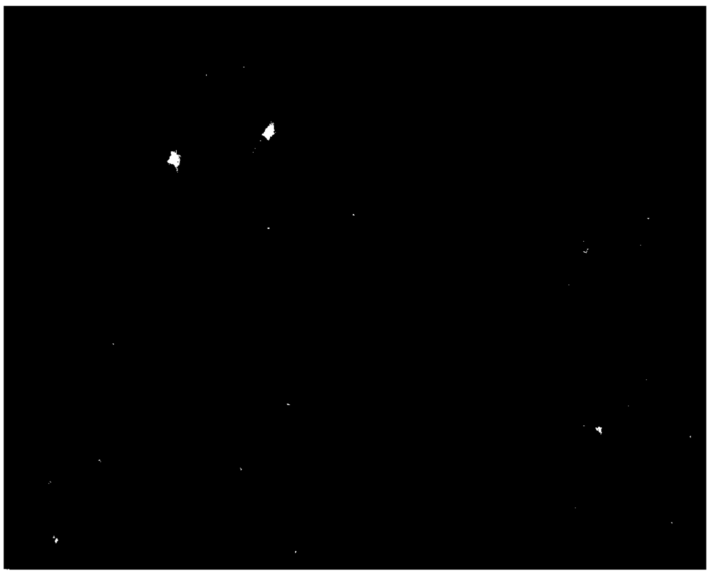

(18) USCG (14) CGR/DC-27/79

Technical Report Documentation Page

1. Report No. (19) [redacted]D-19-80	2. Government Accession No. AD-A084257	3. Recipient's Catalog No.

4. Title and Subtitle

(6) Transitory Fire Resistance of Tanker Lifeboats

5. Report Date (12) February 1980

6. Performing Organization Code

7. Author(s)

(10) David E. Beene, Jr

8. Performing Organization Report No.

R&DC 27/79

9. Performing Organization Name and Address

United States Coast Guard
Research and Development Center
Avery Point
Groton, Connecticut 06340

10. Work Unit No. (TRAIS)

11. Contract or Grant No. 12 32

12. Sponsoring Agency Name and Address

Department of Transportation
United States Coast Guard
Office of Research and Development
Washington, DC 20593

13. Type of Report and Period Covered

(9) FINAL REPORT

14. Sponsoring Agency Code

15. Supplementary Notes

Performed at the U.S. Coast Guard Fire and Safety Test Detachment under the supervision of the U.S. Coast Guard Research and Development Center, Avery Point, Groton, Connecticut.

16. Abstract

This test program evaluated aluminum, steel, and fiberglass lifeboats in one- to three-minute liquid spills fires to determine which type of lifeboat provides superior resistance to a transitory deck fire. Each lifeboat consisted of a half-hull built on a continuous keel bar with side benches, and foam-filled flotation devices. Eight half-hulls, three of aluminum, two of steel, and three of fiberglass-reinforced plastic (FRP), were tested. A specially designed pen permitted videotaping the exterior and interior hull surface during actual fires. A water spray necessary to protect the superior lifeboat during a long-term fire was also calculated and tested.

The results indicated: (1) aluminum lifeboats melt and collapse when exposed to one-minute deck fires, (2) steel lifeboat hulls remain intact, but the interior structures and buoyancy tanks would have to be extinguished before the lifeboat would be useable, (3) FRP lifeboats provide good fire resistance and retain superior lifesaving capabilities, and (4) a water spray application rate of 0.23 gallons per minute per square foot (9.37 liters per minute per square meter) will protect steel and FRP lifeboats in sustained test fires.

17. Key Words	18. Distribution Statement
Lifeboat Aluminum lifeboat Fiberglass lifeboat Steel lifeboat	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

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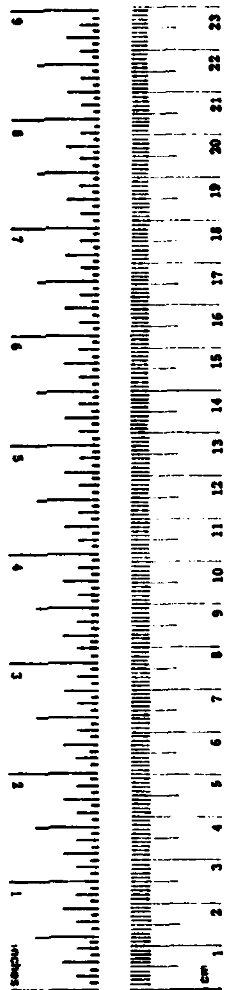
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

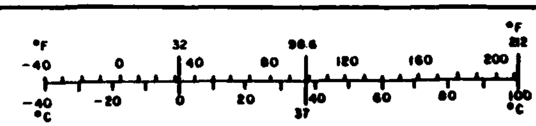
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 BACKGROUND

The collision of the SS KEYTRADER and the SS BAUNE[1] on 18 January 1974 with resulting loss of life raised the question that aluminum lifeboats may provide inadequate short-term fire resistance. The resulting deck fire on the SS BAUNE destroyed one lifeboat completely and rendered a second one unseaworthy by melting the aluminum hulls. Although exposed to the deck fire for only a short time, the lifeboats lost their integrity to function as lifesaving devices as required in Coast Guard Rules and Regulations for Tank Vessels, (Title 46, CFR 33.01-30), which references Title 46, CFR 160.035-2.[2] It is possible that steel or fiberglass lifeboats would have been more effective in resisting the short-term deck fire.

2.0 PROBLEM STATEMENT

In a long intense fire it is unlikely that any of the lifeboats would remain useable without some form of protection. The problem was to determine which type of lifeboat provides superior resistance to a transitory fire.

2.1 Transitory Fires

A transitory fire is one which engulfs an object for a short time but quickly extinguishes itself from lack of fuel. This type fire occurs most often in a collision of vessels, where either one or both are carrying bulk flammable liquids.[3] Upon collision, the liquids are splashed out on the vessel's deck, ignited, and the resulting fire engulfs the lifeboats for a short time. The concern about the rapid destruction of the lifeboats is that the crew may seek to use them once the transitory fire has passed.

2.2 Test Objectives

The purpose of this test series was to investigate the transitory fire resistance of aluminum, steel, and fiberglass-reinforced plastic (FRP) lifeboats. The primary objectives were to:

(1) Investigate specific failure characteristics in aluminum, steel, and FRP lifeboats when subjected to transitory fires.

(2) Record specific temperatures, times, and heat flux levels creating lifeboat failures.

(3) Record and document any lifeboat failures on color videotape.

(4) Evaluate and compare the transitory fire resistance of the different lifeboats.

A secondary objective was to calculate and test the water spray requirement necessary to protect the lifeboats during a sustained test fire.

2.3 Lifeboat Construction

Lifeboats constructed of aluminum, steel, and FRP are approved by the U.S. Coast Guard for use on Merchant Vessels.[2] Reviewing their different properties, we find that aluminum has a low melting temperature.[4] Steel has shown superior fire resistance to aluminum, but is also subject to deformation in intense heat. Fiberglass-reinforced plastic decomposes at a lower temperature than aluminum, but it also contains fire-retardant resins. It is possible that one of the lifeboats provides superior resistance to a transitory fire.

2.4 Water Spray Coverage During Sustained Fires

Previous full-scale lifeboat testing conducted for England's Ministry of Transport,[5] March-April 1960, reported that aluminum, steel, and fiberglass-reinforced plastic hulls could survive a five-minute Class B fire

when covered by an effective water spray. Based on these tests, it is logical to surmise that lifeboats can survive longer sustained fires if the proper water spray coverage is utilized. The approach used in calculating the water spray involved using calorimeters to measure the actual heat flux received by the lifeboats in the transitory fires. Lifeboat failures in these fires provided individual heat flux exposure limits that must not be reached if a water spray is to be effective. Lifeboats not severely damaged in the short-term fires were used in sustained test fires to determine the protection provided by a water spray which was calculated from the recorded heat flux data.

3.0 APPROACH/PROCEDURES

The lifeboat testing took place on Little Sand Island at the U.S. Coast Guard Fire and Safety Test Detachment (F&STD) in Mobile, Alabama. It was conducted in a special test pen fitted with the instrumentation necessary to record temperatures, test time, heat fluxes, and any resultant failures. Color videotape recording was also used to document each test. Lifeboats surviving the short-term fires were used in sustained fires to test the effective protection of the calculated water spray.

3.1 Test Pen and Fuel

The testing was conducted in a steel pen constructed to hold a half-hull lifeboat. The pen was 30 feet (9.1 m) long, 8 feet (2.4 m) wide, 1 foot (0.3 m) deep, and thus covered 240 square feet (22.3 sq m) (Figure 1). One side of the pen was 6 feet (1.8 m) high with a crescent-shaped section removed from it. This opening was slightly smaller than the keel outline of the smallest lifeboat being tested. For each test, a lifeboat was fitted against the 6-foot (1.8 m) coaming and clamped to it. Steel chocks were positioned beneath the lifeboat and welded to the test pen footing to position the lifeboat 2 feet (0.6 m) above the test fuel.

Number 2 marine diesel was used as the test fuel. Fifty gallons (189.3 l) was added to the pen before each short-term test. The fuel was floated atop 6 inches (15.2 cm) of water inside the pen. Two gallons (7.6 l) of naphtha were spread over the fuel before each test to help in ignition. Standard railroad flares were used to ignite the naphtha which in turn ignited the diesel fuel. Flames spread across the entire pen surface in approximately 20 seconds. The addition of fresh fuel before each test assured the presence of lighter hydrocarbons to decrease the time required for total flame involvement of the fuel surface.

3.2 Instrumentation

A computer-controlled data acquisition system was used to collect 30 channels of comparative data during the testing. Ten Type K inconel-sheathed thermocouples were bolted against the exterior of the lifeboat hull and five were bolted against the interior of the hull. Six additional thermocouples were positioned around the test pen and extended one foot into the flames. Ambient temperature, wind speed, and wind direction were also recorded. Two color video cameras were used, one to film the hull exterior and one to film the hull interior (Figure 1).

3.3 Half-Hull Testing

Half-hull lifeboats were used in the testing. This reduced the overall cost and permitted a test arrangement which made it possible to videotape the hull interior during actual fire conditions. Eight half-hull lifeboats, three of aluminum, three of fiberglass-reinforced plastic, and two of steel were tested one at a time in short-term fires.

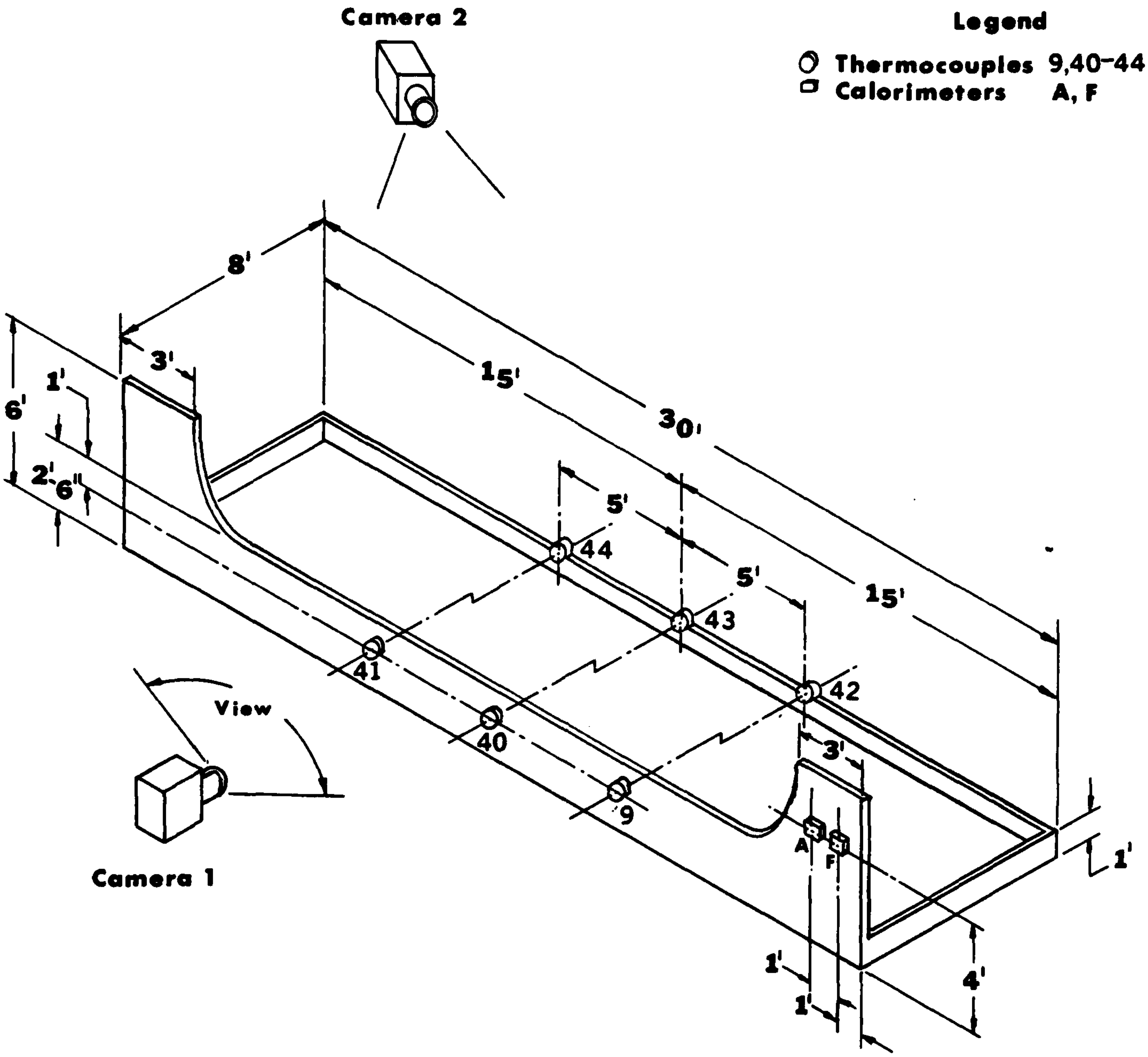


Figure 1

Test Pen and Coaming Dimensions

Each lifeboat was 24 feet by 8 feet by 3.5 feet (7.3 m by 2.4 m by 1.1 m) and was fitted against the interior of the crescent-shaped coaming. Each consisted of a half-hull built on a continuous keel bar from aft to forward (Figure 2). Side benches and foam-filled flotation devices were also included in each hull (Figure 2). The hull, side benches, and flotation units were constructed as specified in Coast Guard approval plans.

3.4 Short-Term Fires

Each lifeboat was tested in a short-term fire. One steel lifeboat was used in two short-term fires. The first three test fires were two minutes long. Each involved a different type lifeboat. The results of the first three short-term fires indicated a need to decrease the test time for the aluminum lifeboats and to increase the test time for the steel and the fiberglass lifeboats.

The original two-minute test time was based on experimental data collected in December 1978 at the US Coast Guard F&STD in Mobile, Alabama. The data showed that mixtures of marine diesel fuel and gasoline, when released on a flat surface, would burn with intensity for only two minutes.

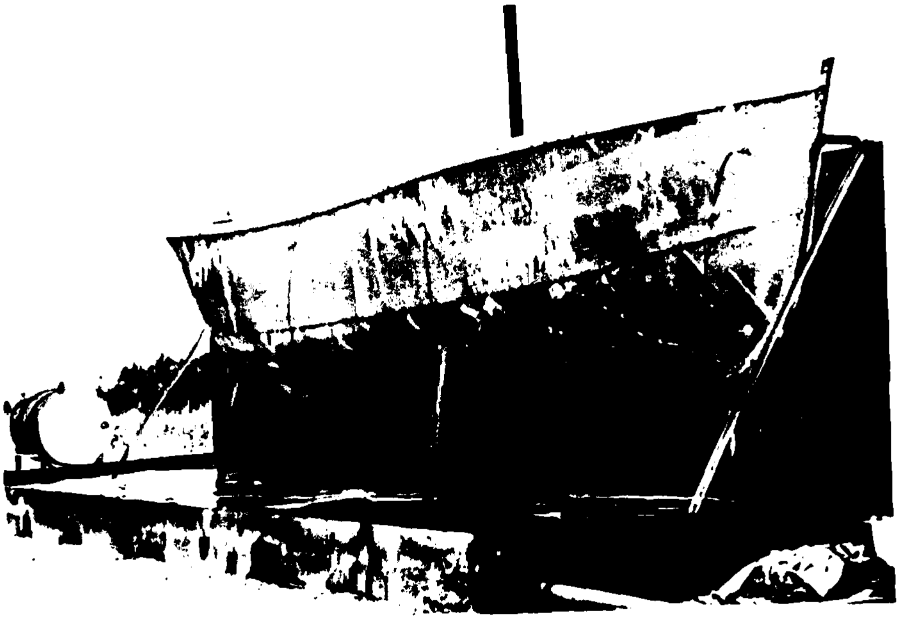
3.5 Calculated Water Spray Coverage

Steel and fiberglass-reinforced plastic lifeboats survived the short-term fires, so two of each were tested in 20-minute fires to investigate the protection that a calculated water spray could provide. Twenty minutes was used as the sustained test fire duration since a shipboard deck foam fire extinguishing system is only required to operate 20 minutes before the vessel is considered past the point of saving and must be abandoned.

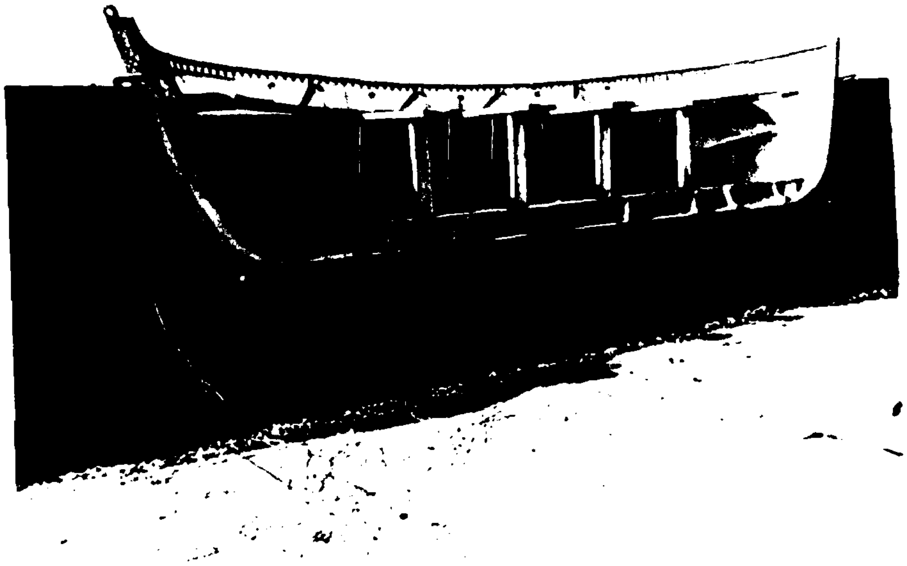
Heat flux data collected from the short-term fires was used in calculating the water spray needed to protect the lifeboats during the 20-minute fires. The method assumes that the maximum heat flux during the short-term fires is the average heat flux incident on the hull surface during a 20-minute fire and then calculates the water spray necessary to absorb it. For this purpose, the hull was considered protected when the calculated heat flux was theoretically absorbed in converting the entire water spray into steam. Expressing this procedure as a formula:

$$WS = \frac{A_s \times H_m}{((212-T_w)\ C_w + H_e)} \times K \times S_f$$

Where
- WS = water spray rate (gallons per minute)
- A_s = half-hull surface area = 150 square feet
- H_m = maximum heat flux from short-term fires = 18 BTU/sq ft/sec
- T_w = temperature of incoming water = $72^{o}F$
- C_w = heat capacity of water = 1 BTU/pound
- H_e = heat required to vaporize water = 971 BTU/pound
- K = a constant to convert from seconds to minutes and pound to gallons = 7.2
- S_f = arbitrary safety factor = 2



Exterior



Interior

Figure 2

Half-Hull Lifeboat

This gives a water spray of 35 gallons per minute (133 liters per minute) as the required protective flow. This flow provides a water spray of approximately 0.23 gallons per minute per square foot (9.37 liters per minute per square meter). This application rate was calculated assuming a uniform spray of water over the entire hull and did not attempt to account for adverse wind conditions or differences in nozzle patterns. A deluge sprinkler system with five sprinkler heads was used to evenly distribute the water over the lifeboat hull. The operating water pressure was 65 pounds per square inch. All other test procedures and instrumentation were identical to those in the short-term fires.

4.0 RESULTS AND DISCUSSION

Sixteen test fires were conducted according to the schedule in Table 1. Eleven were short-term fires which used a half-hull lifeboat per test. Two of these tests (Numbers 13 and 14) were conducted to more thoroughly investigate the ignition of the foam used in steel and fiberglass buoyancy tanks. One additional short-term fire was conducted to measure the heat flux at the center of the test pen. No lifeboat was used in this test and the calorimeters were moved to the center of the pen.

Four sustained test fires were conducted, two on steel and two on fiberglass lifeboats, to investigate the effectiveness of the calculated water spray. Each lifeboat was tested separately.

TABLE 1

LIFEBOAT TEST SCHEDULE

Test Number	Lifeboat	Test Time
1	Aluminum	2
2	FRP	2
3	Steel	2
4	Aluminum	1
5	FRP	3
6	Steel	3
7	Aluminum	1
8	FRP	3
9	Steel	3
10	Calorimeter Check	10
11	FRP	20
12	FRP	20
13	Steel	3
14	Steel	3
15	Steel	20
16	Steel	20

4.1 Conditions During Testing

Two lifeboats were tested per day. The average temperature was 85°F (29.4°C). The wind was constantly changing directions and gusted up to 10 miles per hour. It sometimes blew flames around the ends of the test pen and scorched the lifeboat's interior. When this occurred, it also created smoke conditions which shielded interior sections of the lifeboat from view. These adverse conditions created some minor test delays in the schedule but did not affect the overall test results.

4.2 Aluminum Lifeboats

The lifeboat was constructed of 6061 aluminum alloy in the T6 heat treated condition. Its hull was 0.09 inches (0.23 cm) thick.[2] Fifty seconds into the one-minute test fire an 18 square foot (1.67 sq m) section of

the hull melted and collapsed. At the conclusion of the one-minute test, twenty percent of the hull had melted (Figure 3). At the end of the two-minute test, the entire hull had melted. Only the keel, thwart brackets, and gunwale remained. They were 1.0 inch (2.54 cm), 0.25 inch (0.64 cm) and 0.38 inch (0.95 cm) thick respectively. At the time of the hull failure, the flame temperatures had reached 1560°F (849°C) (Figure 4) and the recorded heat flux was 16 BTUs per square foot per second (Figure 5). At this point, the lifeboat's wooden structures and its fiberglass buoyancy tanks were also aflame. At the conclusion of each test, only the flames in the pen were extinguished. The lifeboat interior and its buoyancy tanks were permitted to burn in order to record length of burning and to determine if they were self-extinguishing. The wooden interior burned itself out six minutes after test pen extinguishment while the foam-filled buoyancy tanks were finally extinguished after twenty-five minutes as they displayed no tendency toward self-extinguishment. The burning foam (rigid polyurethane) in the fiberglass tanks could not be extinguished by dry chemical agents and instead had to be extinguished by using the backup water spray system.

4.3 Steel Lifeboats

The steel hulls remained intact through the short-term fires although the steel buoyancy tanks ruptured and their interior foam caught fire along with the wooden seats and side benches (Figure 6). These would have to be extinguished before the lifeboat would be useable.

The lifeboat hulls were constructed of Number 14 and 16 USSG (United States Standard Gauge) steel.[2] The hulls buckled and bowed to 1.0 inch (2.54 cm) depths but otherwise remained undamaged. The buckling occurred primarily where the handrails were attached to the hull. Immediately after the test fire engulfed each hull, the paint on its surface burst into flames. Soon after this, the interior wooden structures caught fire, the steel buoyancy tanks ruptured, and the interior foam began burning profusely. The ignition of these items was attributed to the heat flux coming through the hull instead of from the heat flux coming over the gunwale. This was confirmed in two additional tests (Numbers 13 and 14) in which protective covers were placed atop the buoyancy tanks. In these tests, videotapes clearly show the point of tank rupture and foam ignition to be the corner of the tank closest to the hull.

The recorded temperatures of the hull interior were well above the ignition temperatures of untreated wooden structures[6] (Figure 7). In fact, the temperatures of the interior surface of the hull were only slightly lower than the temperature of the exterior of the hull (Figure 7) which was in direct flame contact.

4.4 FRP Lifeboats

The FRP lifeboats charred in the short-term fires but were not seriously damaged (Figure 8) even though flame temperatures reached 1688°F (920°C). The charred hull was a poor conductor of heat as evidenced by the extreme heat differential between its interior and exterior surfaces (Figure 9). The fiberglass hull varied in thickness from 1.0 inch (2.54 cm) at the keel to 0.25 inch (0.64 cm) at the gunwale. It was constructed of four or more plies of woven roving fiberglass cloth with a mat of chopped fiberglass

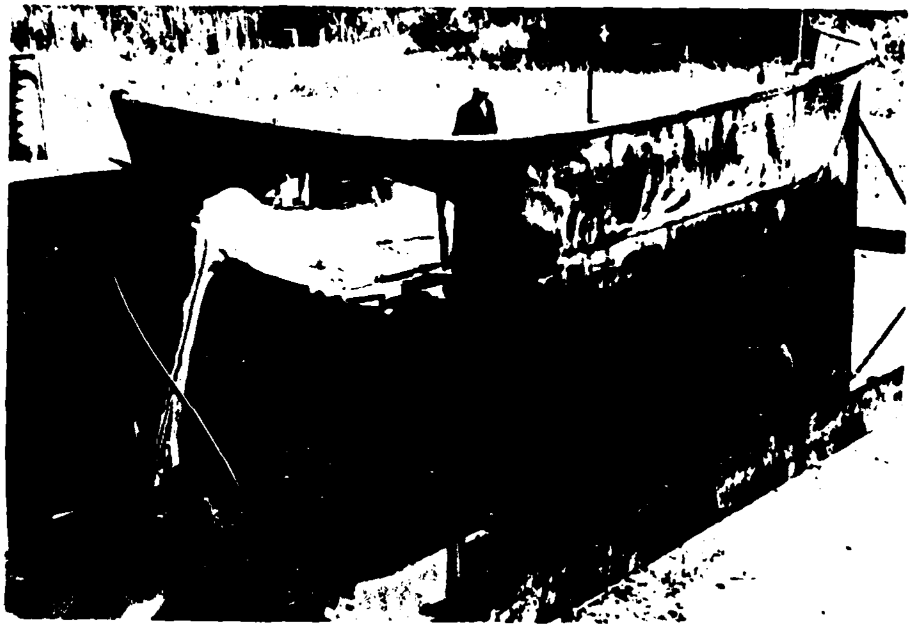


Figure 3

Aluminum Lifeboat Failure

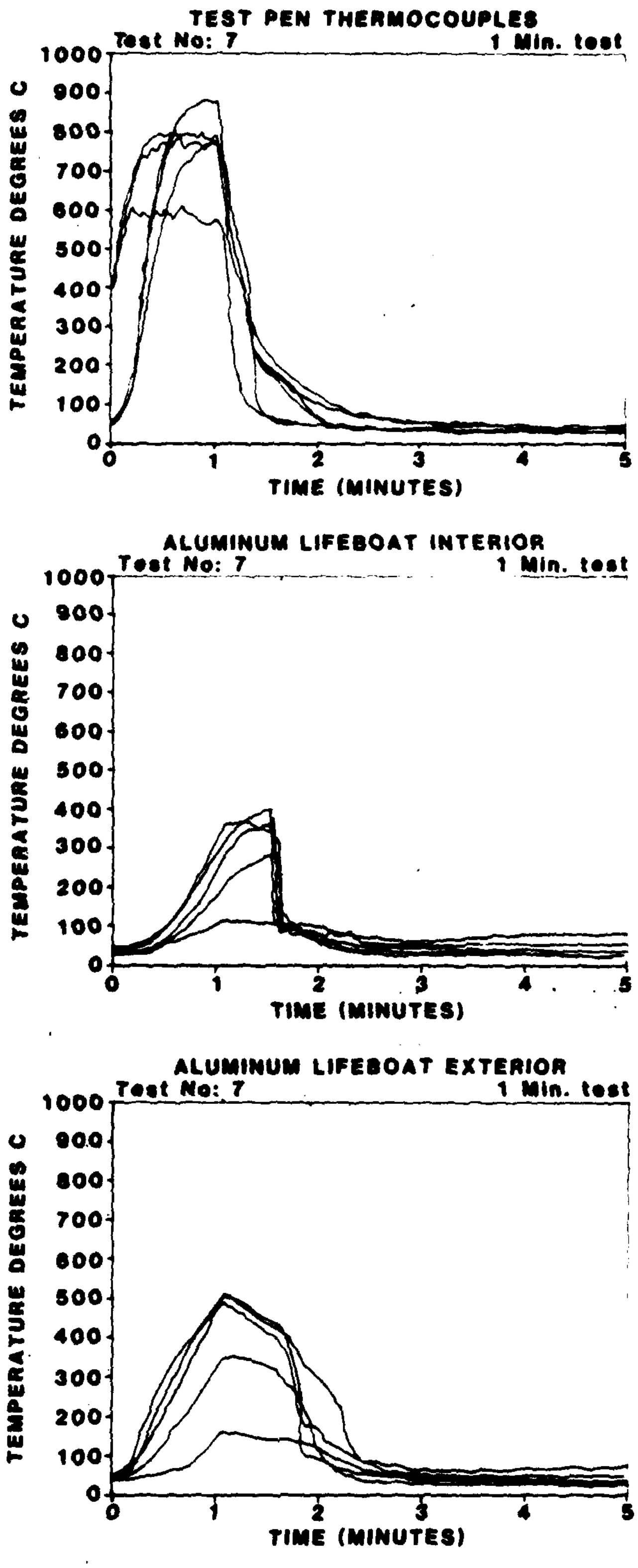


Figure 4

Temperature Histories of an Aluminum Lifeboat in a Short-Term Fire

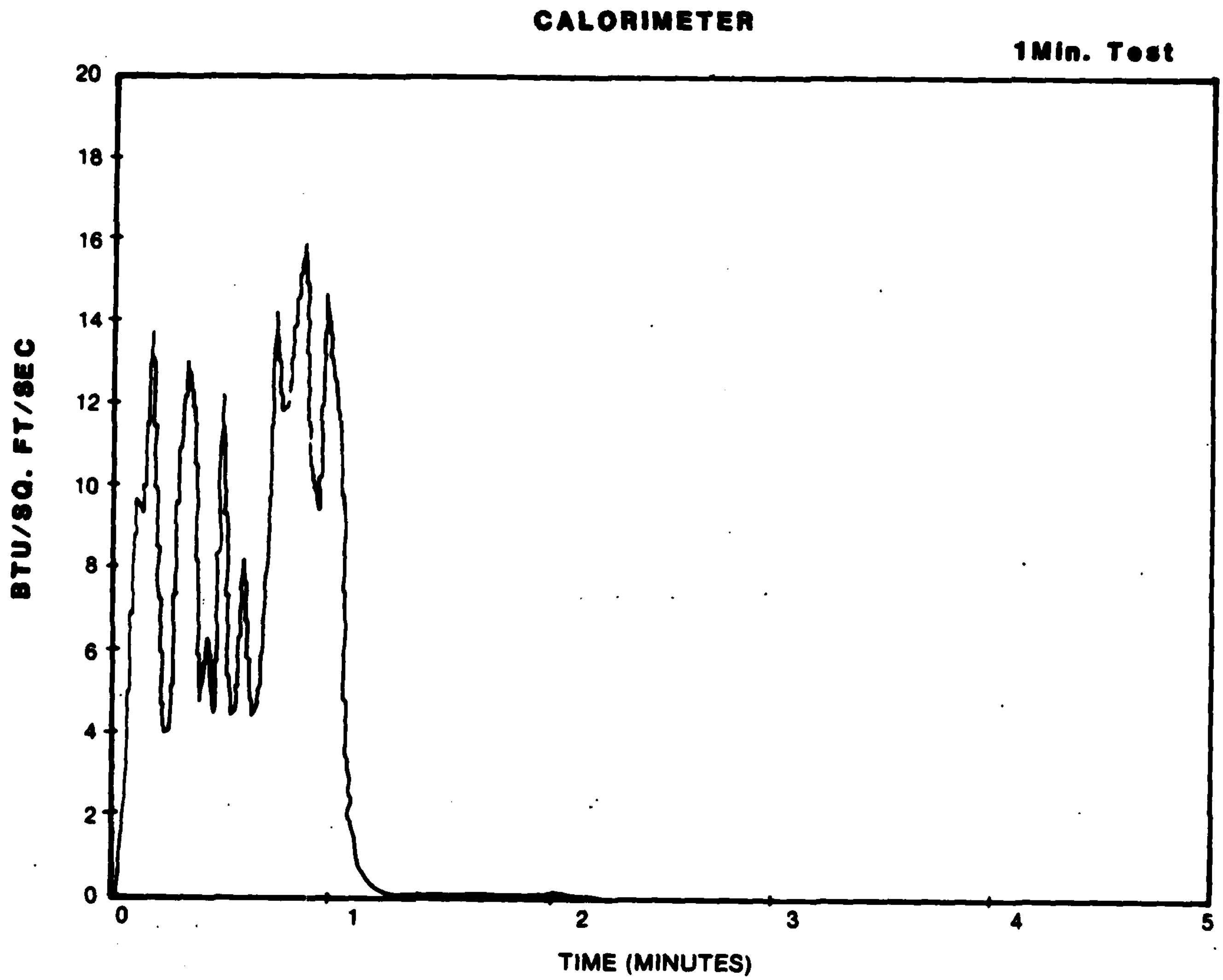


Figure 5

Heat Flux History During a Short-Term Fire

Exterior

Interior

Figure 6

Steel Lifeboat Results

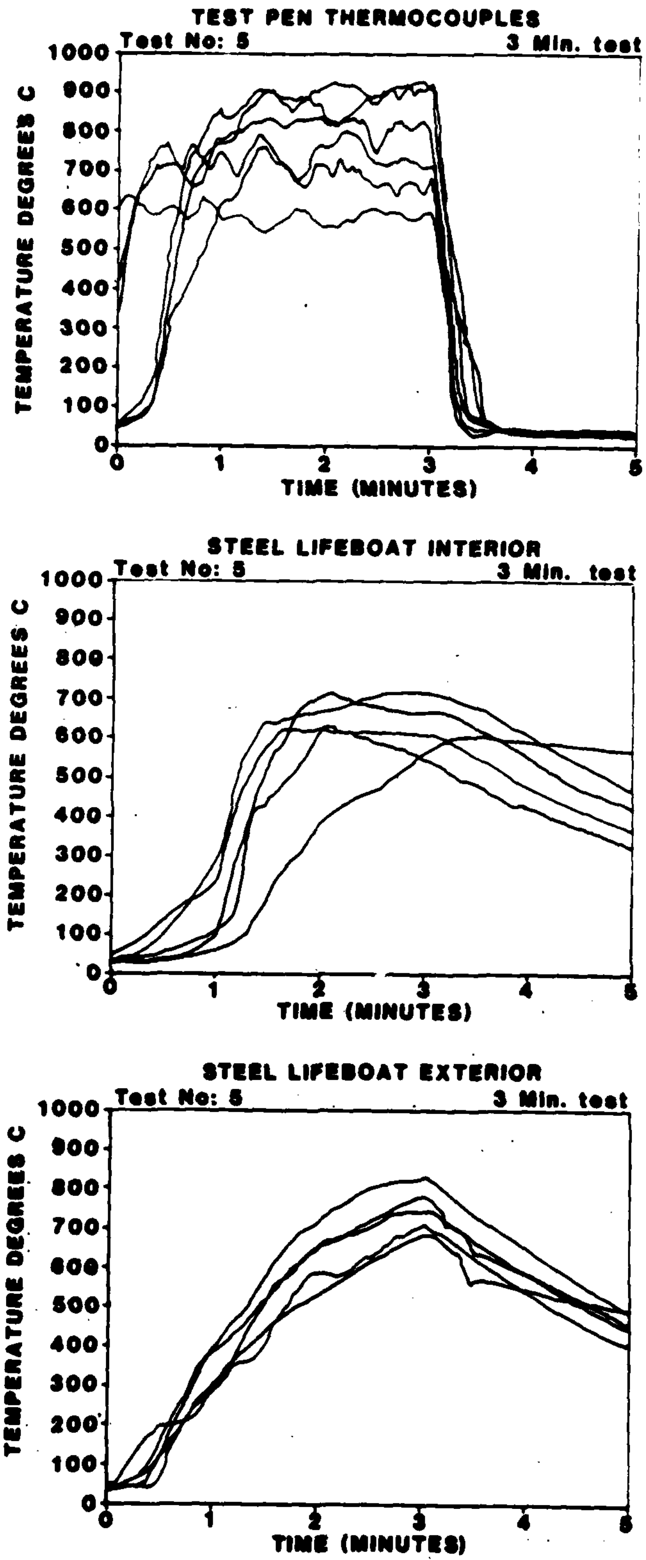
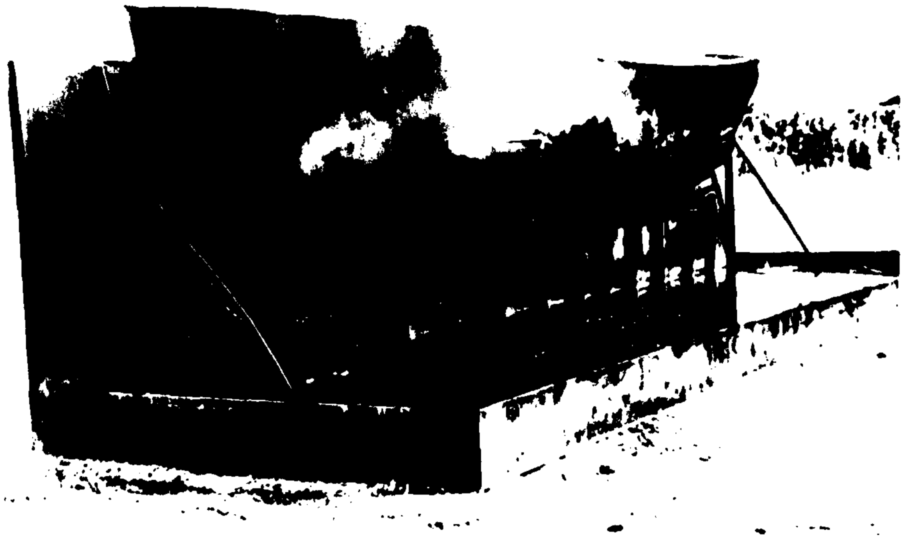


Figure 7

Temperature Histories of a Steel Lifeboat in a Short-Term Fire



Exterior

Interior

Figure 8

FRP Lifeboat Results

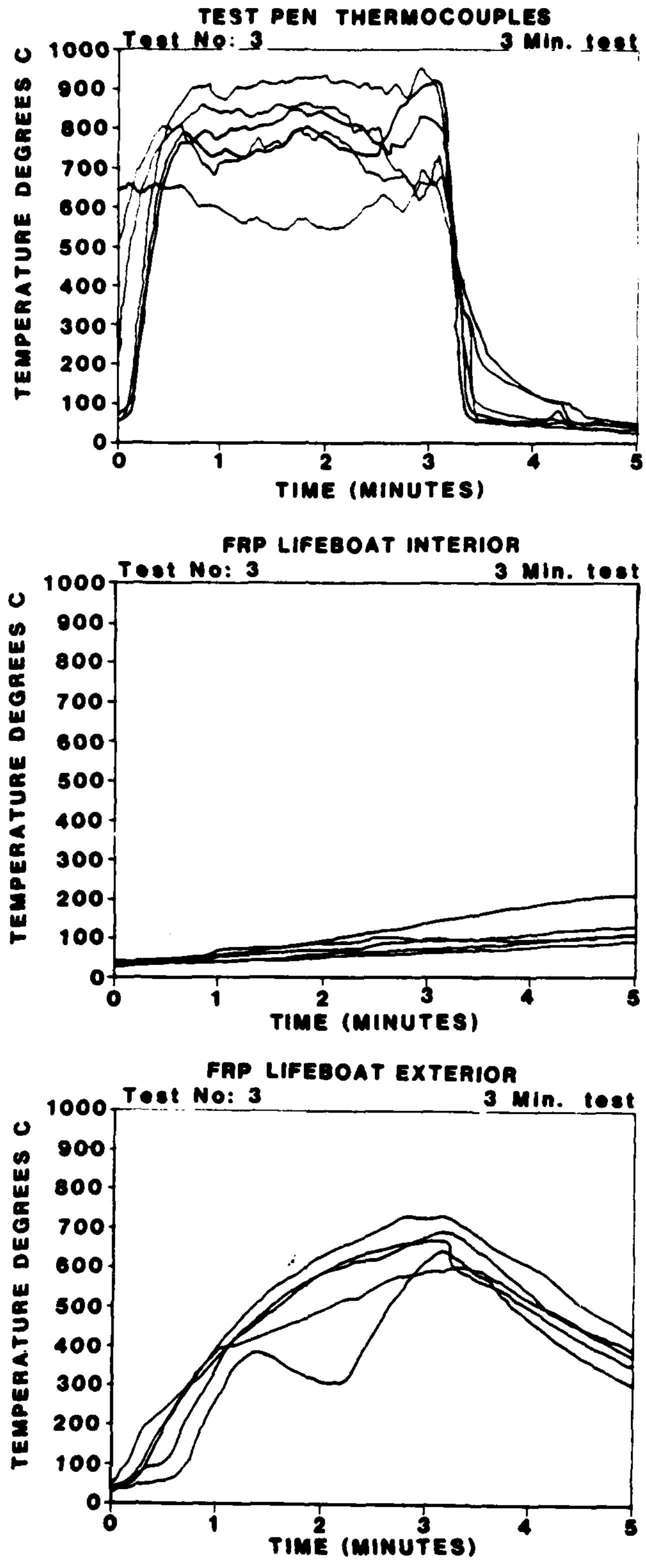


Figure 9

Temperature Histories of a FRP Lifeboat in a Short-Term Fire

strands between each layer. The woven roving and mat plies were laminated together by fire-retardant resin[2] to form a solid bonded structure. In addition, a finishing coat of gel coat covered the hull's exterior while the hull's interior was covered with international orange paint. Although the gel coat burned away immediately, the resin only partially burned in the first two layers of woven roving. It did not burn away completely as evidenced by the fact that the woven roving did not peel away and drop into the test pen. In the three GRP short-term tests, however, the woven roving in one location on each hull did form a bubble 6 inches (15.24 cm) high and 1 foot (0.3 m) in diameter. The hull beneath the bubble, however, remained waterproof and sturdy. The fiberglass in the hulls did not contribute to any burning as it only charred. In addition, once the flames in the test pen were extinguished, the hull quickly extinguished itself.

The interior hull remained intact and waterproof throughout the short-term fires as long as the flames only burned one side of the hull. During two test fires, however, adverse wind blew the flames around the aft and/or forward end of the test pen coaming and burned the resin in the hull from both sides. The woven roving in this location still remained intact, but it was no longer waterproof since the resin had been almost completely consumed by the flames. This weakened section of the hull was approximately 1.5 feet (0.46 m) in diameter. This weakened condition of the hull was created by a combination of the half-hull testing, the test pen construction, and strong winds.

The FRP's buoyancy tank was constructed as a part of the fiberglass hull. In this manner, the exterior hull of the lifeboat also served as a wall for the buoyancy tank. The tank was not constructed as a separate unit and then attached, as was the case of the tanks in the aluminum and steel lifeboats. The FRP buoyancy tank also had thicker walls than the tanks in the aluminum and steel lifeboats. Its wall thickness was 0.25 inch (0.64 cm) or greater. Once constructed, the tank was filled with polyurethane or polystyrene and then sealed.

The buoyancy tanks remained intact, undamaged, and waterproof through the short-term fires. Neither the hull nor the buoyancy tank walls were destroyed by the test fires. After the flames in the test pen were extinguished, samples of the polyurethane foam were removed from the tank and examined. They were neither scorched nor charred. The thicker FRP walls were poor conductors of heat (Figure 9). Although no longer waterproof, the hull was structurally intact with undamaged buoyancy tanks so the lifeboat was still useable. Coast Guard Rules and Regulations require a FRP lifeboat with built-in buoyancy tanks to be capable of supporting its occupants and its required equipment even though it is flooded.

Test results indicating the good fire retardancy of the fiberglass resin is supported by data collected in previous testing done by Underwriters' Laboratories.[7] In the Underwriters' Laboratories testing, ASTM-E-84 tunnel tests rated asbestos-cement board at zero flame spread while red oak, a slow-burning wood, was rated at 100. Fire-retardant fiberglass resins tested out at between 70 to 105 with marine plywood from 150 to 200, and standard resin fiberglass rated from 350 to 500. The lower test values of the fire-retardant resins showed their fire retardancy.

4.5 Steel and Fiberglass Buoyancy Tanks

Two additional short-term tests were conducted using steel lifeboats which contained two steel and two fiberglass buoyancy tanks. The purpose was to determine if the buoyancy tanks caught fire from the heat flux from the hull and not from the heat flux of the test pen flames. To help determine this, a protective cover was placed atop each tank to protect it from the direct heat flux of the test pen flames.

The steel buoyancy tanks were constructed of Number 18 USSG (United States Standard Gauge) steel sheet and filled with rigid polyurethane foam. The fiberglass tanks were constructed of a single layer of woven roving and fiberglass matting which had been laminated with fire-retardant resin and completely covered with gel coat. The tanks were curved on one side so they tended to fit the general curvature of the hull. Because of obstructions in the hull, however, a 1-inch (0.24 cm) gap separated the tank and the hull.

Midway into each test, flames could be seen coming from between the fiberglass tanks and the hull. Following this, the steel tanks ruptured at a seam and flames could be seen spewing from the rupture (Figure 10). It appeared both types of tanks caught fire from the heat flux emitted from the hull since the flames first appeared between the tanks and the hull.

Only the test pen flames were extinguished at the conclusion of the test. Both types of buoyancy tanks were permitted to burn to see if they would extinguish themselves. At 25 minutes, the tanks were extinguished as they gave no indication of self-extinguishing. Only char and ashes remained of the burned foam. No buoyancy properties remained. A dry chemical agent was used to extinguish the fiberglass tanks. The agent was not able to extinguish the steel tanks as the brown gaseous cloud being discharged from them continually reflashed. Instead, copious amounts of water were required for its extinguishment. These tanks would have to be extinguished before a lifeboat containing them would be useable.

Two types of foam, polyurethane and polystyrene, are approved by the Coast Guard for use in buoyancy tanks. Both types should be required to be fire retardant. Although polyurethanes themselves are non-toxic, their pyrolysis products have been shown to contain quantities of toxic gases.[7] Although not tested for in these tests, amounts of hydrogen cyanide have been detected in polyurethane combustion products although the quantities necessary for its relative toxic properties to be a health hazard have yet to be established. It is known that fire retardance can be imparted to polyurethane foams by the chemical incorporation of halogen and or phospherous compounds into the materials.[8]

Polystyrenes have a high rate of combustion and burn rapidly while producing a dense smoke. Other than carbon monoxide, no known highly toxic combustion products are associated with polystyrene.[8] It can also be rendered fire retardant but once ignited by an intense fire, it burns quite rapidly.

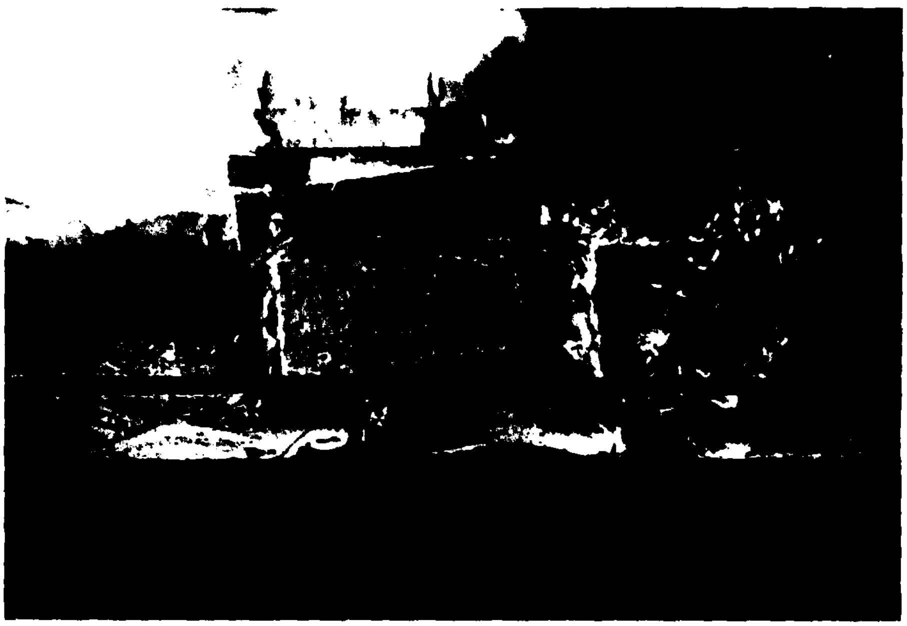


Figure 10

Burning Buoyancy Tanks

4.6 Water Spray Effectiveness

The water spray was effective in protecting the half-hull lifeboats tested in the 20-minute fires (Figure 11). Two steel and two FRP lifeboats were tested one at a time in the sustained fires. The calculated water spray of 35 gallons per minute (133 liters per minute) delivered approximately 0.23 gallons per minute per square foot (9.37 liters per minute per square meter) across the surface of the hull. Five deluge adjustable spray nozzles were used to disperse the water flow. The nozzles were installed 5 feet (1.5 m) apart on a 2-inch (5.1 cm) diameter water pipe which was installed parallel to and 3 feet (0.9 m) away from the lifeboat inside the test pen. The nozzles were 1 foot (0.3 m) above the test fuel and tilted at a 55^{o} angle so that their spray patterns touched each other as well as the gunwale and the keel.

The FRP hulls were more susceptible to damage than the steel hulls in the long-term fires, especially when a nozzle failed or a spray pattern proved inadequate. For example, in Test Number 12, a nozzle malfunctioned for a few minutes and a 3-foot by 3-foot (0.9 m by 0.9 m) layer of woven roving peeled away from the unprotected hull exterior and collapsed into the test pen. The remaining layers of resin and fiberglass, however, still appeared quite firm and waterproof. In addition, at the conclusion of each of the tests two to three bubbles of woven roving, usually 1 foot (0.3 m) in diameter and 0.5 foot (0.15 m) high, would form on the exteriors of the hull. The hull beneath the bubble, however, still appeared firm and waterproof.

The FRP hulls also proved more vulnerable to damage in flames from adverse winds. In the previously mentioned test, the flames blew around the end of the test pen and completely covered the aft section of the hull. As flames engulfed both sides of the lifeboat, the resin in the hull was almost completely consumed in a 2-foot (0.61 m) diameter circle on the hull. Even though almost void of resin at this point, the layers of woven roving and fiberglass mat still remained. The hull in this area was no longer waterproof. The buoyancy tanks were not damaged in the 20-minute fires.

The cooling effect of the water spray can be noted in three distinct patterns during the 20-minute tests involving the FRP lifeboats.

(1) The interior of the FRP hull indicated only a very slight temperature rise, $122^{o}F$ ($50^{o}C$), during the 20-minute fire when compared to the 3-minute fire (Figures 12 and 9). Assuming that the temperature increase is slight because of the water spray, the longer test time does provide the interior of the hull an opportunity to seek a thermal equilibrium with the exterior of the hull. It appears that as the outer layer of woven roving chars, its cloth surface acts as a sponge to hold the water spray against the hull surface to help in cooling.

(2) The exterior hull temperatures were noticeably lower, $392^{o}F$ ($200^{o}C$), in the 20-minute test than in the 3-minute test (Figures 12 and 9).

(3) The three test pen thermocouples in the water spray just below the hull show a considerably lower temperature, $472^{o}F$ ($300^{o}C$), than the three test pen thermocouples which are not protected by the water spray (Figure 12).

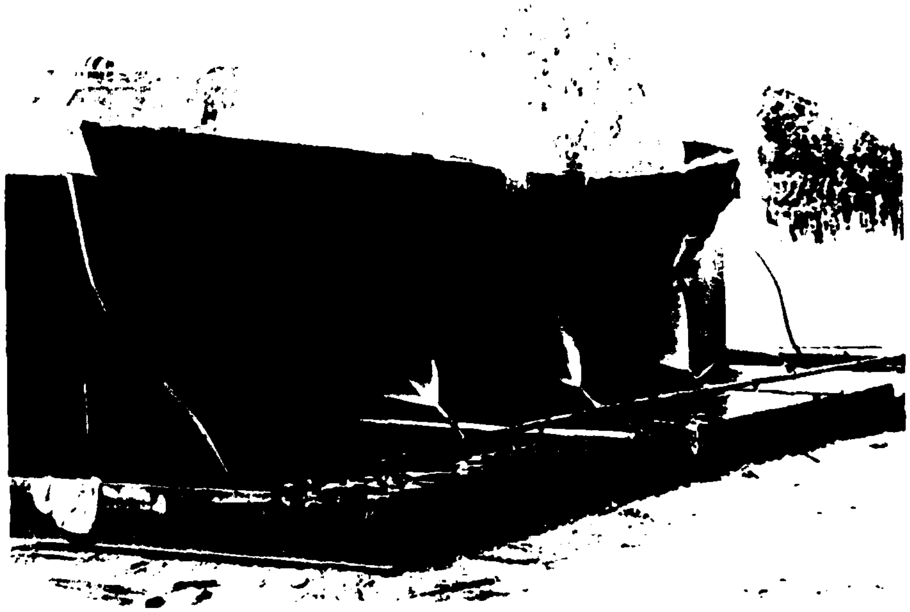


Figure 11

Water Spray Protection

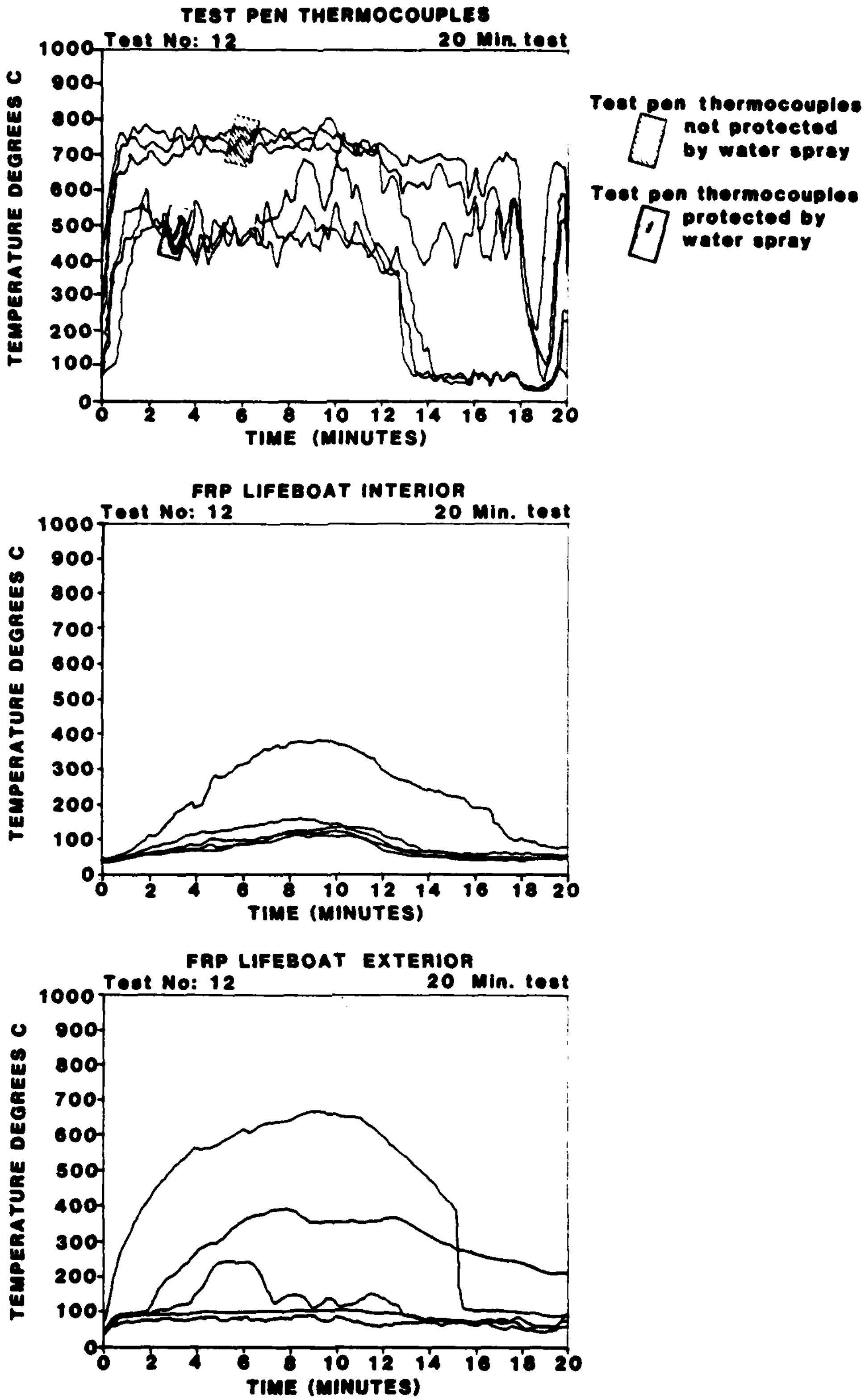


Figure 12

Temperature Histories of a FRP Lifeboat in a Sustained Test Fire with Water Spray Protection

The steel hulls were superior in resisting fire damage in the long-term fires during normal as well as abnormal test conditions. The hull buckled and bowed but still remained waterproof. However, the interior steel and fiberglass buoyancy tanks ruptured, caught fire, and would have required extinguishment before the lifeboat could be useable.

5.0 SUMMARY/CONCLUSION

Aluminum lifeboat hulls melt and collapse when exposed to temperatures experienced in short-term deck fires. In addition, their fiberglass-reinforced plastic buoyancy tanks burn easily and are self-sustaining until only char and ashes are left. The rapid destruction of the hull, the ease of fiberglass buoyancy tanks to burn completely, and the difficulty required to extinguish them, make the aluminum lifeboat the least desirable in terms of fire protection integrity.

Steel lifeboat hulls are not damaged by short-term fires, but interior structures such as the foam-filled buoyancy tanks, seats, and side benches will ignite from the hull's heat flux and would require extinguishing before the lifeboat is useable. In addition, the burning buoyancy tanks burn profusely, are self-sustaining, are difficult to extinguish, and will burn until only char and ashes are left, thereby losing their buoyancy properties. Although the steel hulls remain waterproof in short-term fires, the lifesaving capabilities of the lifeboats are severely reduced with the combustion of wooden interior and its buoyancy tanks.

FRP lifeboats provide good resistance against short-term deck fires. The hull's numerous layers of fiberglass laminated with fire-retardant resins act as poor heat conductors to protect the hull, its interior, and its buoyancy tanks. The FRP buoyancy tanks are constructed as an extension of the hull, have the same wall thickness, and, therefore, exhibit the same degree of good fire resistance. The tanks remained undamaged in the testing and thus would keep a flooded lifeboat and its occupants afloat. The good fire resistance and poor heat conductivity of the hull and its fiberglass buoyancy tanks makes the FRP lifeboat superior in lifesaving capabilities in short-term fires.

A water spray application rate of 0.23 gallons per minute per square foot (9.37 liters per minute per square meter) was effective in protecting the steel and the FRP lifeboats during the 20-minute test fires. The FRP lifeboat was no longer completely waterproof, but it still retained its lifesaving properties. The steel lifeboat was still waterproof, but its interior structures and buoyancy tanks would require extinguishing before being useable.

The foam in steel buoyancy tanks and in single-layered fiberglass buoyancy tanks ignites easily, burns profusely, and offers no short-term fire resistance.

REFERENCES

1. National Transportation Safety Board and U.S. Coast Guard. SS KEYTRADER AND SS BAUNE (Norwegian); Collision in the Mississippi River. Marine Casualty Report, Washington, D.C.

2. Department of Transportation, Coast Guard, Specifications, Subchapter Q (Title 46, CFR Part 165.035 inclusive).

3. National Transportation Safety Board and U.S. Coast Guard Collision SS TEXACO MASSACHUSETTS (U.S. registry) AND MV ALVA CAPE (British registry). Marine Casualty Report, Washington, D.C.

4. American Society for Metals. Metals Handbook. Eighth Edition, 1966.

5. Ministry of Transport, England, Tanker Lifeboat Fire Tests, March-April 1960.

6. National Fire Protection Association, Fire Protection Handbook, 14th Edition, Boston, Massachusetts, 1976.

7. Purosky, William, The Advantages of Fire Retardant Fiberglass Laminates for Boats. Durez Div., Hooker Chemical Corp., North Tonawanda, New York.

8. National Materials Advisory Board. Elements of Polymer Fire Safety and Guide to the Designer. Publications NMAB 318-5 National Academy of Sciences, Washington, D.C. 1979.

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